International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 11, Issue 4, Aug 2021, 355-366

PREDICTING PHYSICS TEACHERS' EFFECTIVENESS IN SECONDARY SCHOOLS BY THEIR SUBJECT-MATTER KNOWLEDGE, PEDAGOGY AND TECHNOLOGICAL KNOWLEDGE

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ABSTRACT

This study explored how subject-matter, pedagogical, and technological knowledge of Physics teachers predict their teaching effectiveness in secondary schools using a correlational research design.A sample of 272 senior secondary III physics students and teachers in Akure Education Zone of Ondo State participated in the study. Four researchers' developed instrumentswere used to gather data for the study. Simple linear regression analysis was used to analyse the data. It was found thatthe three teachers' professional knowledge (SMK, PCK, TK) predict physics teachers' effectiveness in secondary schools. While, both SMKand PCK significantly predict teachers' effectiveness in secondary school physics; knowledge of technology does not significantly predict teachers' effectiveness in secondary school physics. Thus, SMK, PCK, and Knowledge of Technology are major determinants of Physics teachers' effectiveness in secondary schools. It was recommended among other things that: teachers should endeavor to present physics contents to enhance stable and consistent understanding in students for better performancein Secondary School Physicsas well as competence in their teaching profession.

KEYWORDS: Subject-Matter Knowledge, Pedagogical Content Knowledge, Technological Knowledge, Students' Academic Achievement & Teachers' Effectiveness

Received: Jun 13, 2021; **Accepted**: Jul 03, 2021; **Published**: Jul 21, 2021; **Paper Id.**: IJMPERDAUG202127

Original Article

1. INTRODUCTION

Student-related factors, social-cultural factors, and school-based factors are three categories of factors that affect students' performance in schools. Of these three, the school-based factor is critical to this study.And, teachers are the most important school-based factor because of their responsibilities concerning student achievement(Keller, Neumann, & Fischer, 2016). Several challenges directly or indirectly affect Nigerian teachers and cumulate to adversely affect secondary schoolsteaching and learning (Idakwoji, 2016).

Not with standing the challenges, one of the bases for assessing teachers' instructional practices in their classroom is teacher knowledge (Lee, Capraro& Capraro, 2018). One of the important indicators of a teacher's competencyis teachers' professional knowledge (Ding, He and Leung, 2014) and a competent teacher is an effective teacher in the classroom. There exists a significant relationship between teachers' effectiveness and student's achievement (Oviawe, 2016). In the same vein, one of the important factors in determining students' achievementis teacher quality (Guerriero, 2016).And student achievement is considered a desirable outcome of school instruction

(Keller et al., 2016). This implies that teacher-related factors might contribute to poor students'academic achievement.

Frantic efforts have been made by researchers in science education to find solutions to the problem of poor achievement of students as caused by teachers. The research reports by mathematics educators in the area of teacher professional knowledge are significant compared to their physics counterparts, being mathematically related aspects of sciences.Such effort recently made by Mathematics educators in the aspect of subject matter knowledge and pedagogical content knowledge includesLee et al. (2018) who revealed the importance of professional development for teachers' pedagogical knowledge in problem posing.

SMK has been defined as "emphasizing knowledge and understanding of facts, concepts, and principles and how they are organized, as well as knowledge about the discipline" (Even, in Lee, et al., 2018). The study of Lee et al. (2018)found that teachers' subject matter knowledge (SMK), knowledge of content and teaching (KCT), and knowledge of content and students (KCS) are related.Teachers' knowledge of content and teaching is the same as teachers' (PCK) in any subject area. Subject matter knowledge is supportedby Bruner's (1978) theory of instruction.

1.1 Theoretical background

Brunner's major concern was to determine how individuals actively select, retain, and transform information (or Subject Matter) which is the main essence of learning.The major implication of Bruner's hypothesis is that teacher should modify their concept of readiness (against the view of readiness in Jean Piaget) to include not just the child but also the content or subject matter. Thus, the researcherssubstantiate the theory by establishing the relationship between teachers'SMK and teachers' effectiveness.PCK is conceived as a tool or vehicle used by teachers to deliver the content knowledge in teachers' minds to students in a comprehensive manner. Therefore, for a teacherto select an appropriate way to convey physics ideas,a profound understanding of the SMKis ultimately needed.This is contrary to the view of Rowan et al.whobelieved that the analytic distinction between teachers' SMK and teachers' knowledge of Pedagogy is fading in large part, due to Lee Shulman's work on teachers' PCK. Kleickmann et al. (2013) buttress this fact.

Theory of instruction according to Bruner links sequencing or arrangement of content (SMK) during a presentation withstudents' learning.According to Bruner (1978), structuring the form of knowledge to achieve a particular instructional objective is the task of the teacher. This is termed teachers' Pedagogical Content Knowledge in this study.This theory suggests that a teacher should know how best to utilize different patterns to bring the subject matter to the level of the learner. In Niess et al. (n.d), TPCK is referred to as the knowledge that interconnects TK, CK, and PK. Several kinds of research conducted in Mathematics have advocated for teachers'preparation in TPCK. For example,Niess (2005) examined the TPCK preparedness of student teachers in multi-dimensional science and mathematics.Handal et al. (2013) explore among secondary mathematics teachers the integration of TPCK in the teaching ofsecondary mathematics. This implies that teachers' knowledge of technology (as measured in TCK, TPK, and TPCK) might form a bond with teachers'effectiveness in secondary schools especially in the domain such as Physics, as reported in Mathematics.

1.2. Review of Relevant Literature

It is vivid that students will learn in a harmonious classroom environment created by an effective teacher.Hill & Chin, (2018) found the connections between teacher knowledge of students, instruction, and achievement outcomes.Oviawe(2016) revealed that teachers' effectiveness is significantly related to students' achievement.Ogbonnaya (2011) found a positive bond exists between teachers' subject matter knowledge and student opportunity to learn the

subject matter provided by the teacher, as well as students' achievement in Mathematics.Kiamba, Mutua, & Mulwa, (2018) found that students' achievement is determined by teacher's subject matter knowledge.Olaniyan (n.d) found that teachers' subject content knowledge has a positive significant relationship with students' achievement.Baumert et al. (2010)found a significant relationship between student achievement and teachers' mathematical content knowledge.Kirschner, Borowski and Fischer (2011) found the correlation between PCK and CK and revealed that physics content knowledge and pedagogical content knowledge are closely connected.

Teacher pedagogical content knowledge positively predicted students' achievement in physics (Keller, Neumann & Fischer, 2016).Gess-Newsome, (2013) found that PCK significantly determines students' learning and achievement. Dinget al. (2014)found that professional and pedagogical competence gives a positive effect on the performance of junior high school science teachers. Also, Campbell et al.(2014) found that the mathematical content and pedagogical knowledge of teachers had significant positive relationships with students' mathematicsachievement.Baumert et al. (2010) found student achievement and teachers' mathematical content knowledge are significantly related.Patra and Guha (2017)found no significant difference in PCK and teacher effectiveness regarding teachers' qualification variation and teachers' experience variation. Similarly, PCK and teacher effectiveness does not differ significantly in respect of teachers' experience and qualification variation.Niess (2005) provided the beginning for understanding TPCK and preparing teachers to teach with technology. Handal et al. (2013) confirmed thatthe TPCK of teachers in mathematics is related to teachers' technological skills.

1.3 Problem Statement and Objectives

Teachers are recognized as the most important school-based factor because of their roles in facilitating teaching and learning. However, student outcome whether measured using standardized test items or not remains the evidence of teaching and learning in secondary school. Thus, there exists a connection between students' achievement or outcome and effective teaching and learning. Teachers' professional knowledge (i.e. SMK, PCK, and TK) is a necessity as reported by mathematics educators for better students' outcomes. The studies reviewed thus far have shown that there is limited research report in this aspect of knowledge under physics education.Apart from the fact that most of the literature reviewed are foreign, no research reporthas shown the nature and magnitude of the relationship among SMK, PCK, and TK using correlation coefficient and regression analysis.These gaps in literature necessitated the current study. This study sought to determine the amount of variations inteachers' effectiveness in secondary school physics that can be attributed to their knowledge of the subject matter, pedagogy, and technology.

1.4 Hypotheses

Ho_1:the amount of variation in teachers' effectiveness in secondary school physics that is attributed to their subject matter knowledge is not significant.

Ho_2: the amount of variation in teachers' effectiveness in secondary school physics that is attributed to their pedagogical content knowledge is not significant.

Ho_3:the amount of variation in teachers' effectiveness in secondary school physics that is attributed to their knowledge of technology is not significant.

2. Research Method

Research paradigm and approach

This research is based on the assumptions of Jerome Bruner's theory of Instruction and Elaboration theory by Charles Reigeluth and his colleagues. Bruner believes that any idea, body of knowledge can be presented in such a form that it is simple enough for any learner to understand it. This belief pushes the frontier knowledge of the role of structuring content knowledge to achieve the instructional objective and this is the peculiar task of a teacher. This emphasized the representation of SMK and the Knowledge of how best to teach it (i.e PCK) in the domain such as Physics. This research adopted a pure quantitative research approach.

Research Design

This study adopted a correlational survey research design that indicates the direction, magnitude, and strength of the relationship between the variables. Ugwuanyi and Okeke (2020), Ugwuanyi et al. (2020a, b, c), Achagh et al. (2020), Eya et al. (2020), Ezema et al. (2019), Gana et al. (2019), have used this design in similar studies.

Population, Sample Size, and Sampling

The participants for this study were gotten from a population of SS III PhysicsStudents and their teachers for 2018/2019 academic session in all the government-owned secondary schools in Akure Education Zone of Ondo State. Their population is 5713 (i.e. 5,581 Physics students and 132Physics teachers respectively). The population includes 839 students from Akure North, 2,245 students from Akure South, 1,102 students from Idanre, 1,382 students from Ifedore. The sample size for this study was 272. It consisted of 17 Physics Teachers and 255 Senior Secondary III Physics Students. A multistage sampling technique was adopted. Firstly, the Proportionate Stratified Random Sampling technique was used to select seventeen (17) schools out of the fifty-three schools contained in the population. The proportions are as follows: 15% (1) school from Akure North, 35% (10) schools from Akure South, 25% (3) schools each from Idanre, and 25% (3) schools each from Ifedore L. G. A. The reason for using a proportionate stratified random sampling technique was because the schools are in their different respective LGA's (i.e. different strata) and to ensure greater representativeness of the sample relatives to the population this technique was adopted. Secondly, the seventeen (17) SS III physics teachers in all the sampled schools were selected purposively. The reason for the choice of purposive sampling technique in the selection of physics teachers was because the researchers intended to select specific elements which would satisfy some predetermined criteria for the study (i.e. SSIII physics teachers who possess technological and pedagogical content knowledge in physics). Thirdly, fifteen (15) SS III physics students were selected from each sampled school using a simple random sampling technique. (i.e. $15 \times 17 = 255$ students).This was used in order to give each student in the sampled schools an equal chance of being sampled for the study.

Instrumentation

Four instruments were employed for this study, namely; Physics Teachers' Subject-Matter Knowledge Test (PTSMKT), Physics Teachers' Pedagogical Competency Questionnaire (PTPCQ), Physics Teachers' Technological CompetencyInventory (PTTCI) and Students' Academic Achievement Score Template (SAAST). Handal, et al., (2013) Technological Competency Inventory was adapted for this study. It was developed for Mathematics. In this study, the researchers changed the concept of Mathematics to Physics.

Data Analyses

The coefficient of determination, which is an aspect of linear regression, was used to answer the research questions, while analysis of variance (ANOVA) was used to test the null hypotheses at a 5 percent probability level.

3. RESULTS

Ho_1:The amount of variation in teachers' effectiveness in secondary school physics that is attributed to their subject matter knowledge is not significant.

Table 1:Regression and Analysis of Variance of the relationship between teachers effectiveness in secondary school physics attributed to their subject matter knowledge.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	
1	.750[a]	.563	.534	.2981	

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.717	1	1.717	19.317	.001[b]
	Residual	1.333	15	.089		
	Total	3.049	16			
a. Dependent Variable: Students Academic Achievement in Physics						
b. Predictors: (Constant), Physics Teachers Subject Matter Knowledge						

The result in **Table 1** showed that the coefficient of determination for the relationship between physics teachers' effectiveness in secondary schools, based on their students' achievement inphysics, and their subject matter knowledgeis 0.563. This implies that 56.3 percent variation in physics teachers' effectiveness in secondary schools is due to their subject matter knowledge. **Table 1** also showed that the amount of variation in teachers' effectiveness in secondary school physics due to their subject matter knowledge is significant at F (1, 15) = 19.317, p = 0.001. The null hypothesis was rejected at $p < 0.05$. The inference drawn was that teachers' subject matter knowledgesignificantly predicts their teaching effectiveness in secondary school Physics.

Ho_2: The amount of variation in teachers' effectiveness in secondary school physics that is attributed to their pedagogical content knowledge is not significant.

Table 2: Regression and Analysis of Variance of the relationship between teachers effectiveness in secondary school physics attributed to their pedagogical contentknowledge

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	
1	.655[a]	.429	.391	.3407	

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.308	1	1.308	11.271	.004[b]
	Residual	1.741	15	.116		
	Total	3.049	16			
a. Dependent Variable: Students Academic Achievement in Physics						
b. Predictors: (Constant), Physics Teachers Pedagogical Content Knowledge						

The result in **Table 2** showed that the coefficient of determination for the relationship between physics teachers' effectiveness in secondary schools, based on their students' achievement inphysics, and their pedagogical content knowledgeis 0.429. This implies that 43 percent variation in physics teachers' effectiveness in secondary schools is due to their pedagogical content knowledge. **Table 2** also showed that the amount of variation in teachers' effectiveness in

secondary school physics due to their pedagogical content knowledgeis significant at F (1, 15) = 11.271, p = 0.004. The null hypothesis was rejected at $p < 0.05$. The inference drawn was that teachers' pedagogical content knowledgesignificantly predicts their teaching effectiveness in secondary school Physics.

Ho_3:the amount of variation in teachers' effectiveness in secondary school physics that is attributed to their knowledge of technology is not significant.

Table 3:Regression and Analysis of Variance of the relationship between teachers effectiveness in secondary school physics attributed to their knowledge of technology.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.330[a]	.109	.049	.4256

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.332	1	.332	1.831	.196[b]
	Residual	2.718	15	.181		
	Total	3.049	16			

a. Dependent Variable: Students Academic Achievement in Physics
b. Predictors: (Constant), Physics Teachers TechnologicalKnowledge

The result in **Table 3** showed that the coefficient of determination for the relationship between physics teachers' effectiveness in secondary schools, based on their students' achievement in physics, and their knowledge of technologyis 0.049. This implies that a 5 percent variation in physics teachers' effectiveness in secondary schools is due to their knowledge of technology. **Table 3** also showed that the amount of variation in teachers' effectiveness in secondary school physics due to their knowledge of technologyis insignificant at F (1, 15) = 1.831, p = 0.196. The null hypothesis was not rejected because the probability value 0.196 was greater than 0.05. The inference drawn was that teachers' knowledge of technologydoes not significantly predict teachers' effectiveness in secondary school Physics.

DISCUSSIONS AND CONCLUSIONS

The study sought to find out how physics teachers'subject matter,pedagogical and technological knowledge predictstheir teaching effectiveness in secondary school. Findings of the study revealed that the three teachers' professional knowledge (subject matter knowledge, pedagogical content knowledge and technological knowledge)predict positively physics teachers' effectiveness in secondary schools. Thus, subject matter knowledge andpedagogical content knowledge significantly predict physics teachers' effectiveness in secondary schools. However, knowledge of technologydoes not significantly predict physics teachers' effectiveness in secondary schools. These findings are in agreement with the findings of the recent studies (Hill & Chin, 2018; Oviawe, 2016; Lee, et al., 2018; Ogbonnaya, 2011; Campbell et al., 2014; Baumert et al., 2010; Kiamba, et al., 2018; Dingetal.,2014; Keller, et al., 2016; Bingimlas, 2018; Handal, et al., 2013; Niess, 2005; Niess, et al., (n.d)).

Following the teaching quality model, we assumed that student outcomes are the result of quality teaching or instructionalfeatures, and (Kunter et al., 2013) differences in teacher quality can be explained byteacher characteristics.The results of the present study supported this assumption by confirmingthat the three-teacherprofessional knowledge (SMK, PCK,and TK) predicts student achievement and in turn determines teacher effectiveness in secondary schools in the domain of Physics. Oviawe(2016) found that teachers' effectiveness is an important predictor of students' achievement.Ugwu et al., (2019) found that the physics teachers were effective in all the factors of physics teaching effectiveness. They demonstrated the greatest effectiveness in the knowledge of subject matter and least effectiveness in

content coverage.Lee, et al., (2018) revealed that mathematics teachers had SMK of problem posing, but their actual problem-posing results did not reflect their SMK well for students' mathematical development. Abdul-Manaf,et al., (2015) found that subject-matter knowledge is significantly related to teachingeffectiveness.Campbellet al., (2014) found a significant relationship betweenupper-elementary teachers' mathematical content knowledge and their students' mathematics achievement after controlling for student- andteacher-level characteristics.Ogbonnaya (2011) found a positive bond exists between teachers' subject matter knowledge and student opportunity to learn the subject matter provided by the teacher, as well as students' achievement in Mathematics.Kiamba, Mutua, & Mulwa, (2018) established that; a teacher's subject matter knowledge had a significant influence on students' achievement in the Kiswahili language.Olaniyan (n.d) found that teachers' subject content knowledge has a positive significant relationship with students' achievement. Baumert et al., (2010) found a statistically significant relationship between student achievement and teachers' mathematical content knowledgeas well as between student achievement and teachers' pedagogical content knowledge for mathematics.Kirschner, Borowski and Fischer (2011) found the correlation between PCK and CK and revealed that physics content knowledge and pedagogical content knowledge are closely connected.In finding a significantly similar positive effect of SMK on teacher effectiveness as measured by their student's achievement, as well as PCK and SMK, the present study corroborates these previous findings also in the domain of physics.

The finding ofDinget al. (2014) reported that professional and pedagogical competence gives a positive effect on the performance of junior high school science teachers, strengthens the present findings on the fact that pedagogical knowledge is germane in the teaching profession, and a key determinant of teacher effectiveness. And, found the connection between subject matter knowledge and pedagogical content knowledge among a group of Chinese pre-service mathematics teachers on the topic of three-term ratio, after the results had suggested an unstable and inconsistent understanding of pre-service teachers on the concept of ratio, which influenced the difference in their presentation of the concept of three-term ratio. Also, Campbell, et al., (2014) found a statistically significant bondbetweenteachers' mathematical content knowledge,teachers' pedagogical content knowledge, and students' achievement in the domain of Mathematics.

Meanwhile, physics teachers' knowledge of technology and its interrelatedness with ICT Skills in teaching and learning gave rise to TCK, TPK, and TPCK. TPCK is at the core. Its knowledge interconnects TK, CK,and PK.TPCK inventory was used in the present study, showing holistically technological pedagogical content knowledge in the physics domain, but the result shows no significant prediction on physics teachers' effectiveness in secondary schools. However, technological knowledge predicts physics teachers' effectiveness in secondary schools, but the prediction was not significant. Bingimlas (2018)found a statistically significant difference between technological content knowledge and teaching experience.Alhababi (2017)found that the TPCK framework is an effective tool for both teachers and students to enhance teaching and learning if it is well implemented and used. Though, the study of Niess, (2005) provided the beginning for understanding TPCK and preparing teachers to teach with technology.

RECOMMENDATIONS

- Teachers should endeavor to present physics contents clearlyas to enhance stable and consistent understanding in students for better performance secondary school physics as well as in their teaching professional competence.
- Teachers should be trained on how to improve their technological pedagogical content knowledge in Physics and

generally in sciences.

- Teachers are to attend workshops and conferences for better improvement in their teaching professions and government should provide the necessary support for them.
- School authorities (private or government) should provide adequate facilities to encourage the application of technological knowledge inthe teaching and learning of Physics.

ACKNOWLEDGEMENTS

The researchers acknowledged all the people who made this research a success especially the participants. We equally appreciate **Nwaghaluke, Johnbosco Eberenna**for serving as the corresponding author for this research.

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